Research Memorandum

THE EFFECTS OF PAIRING, REST INTERVALS, SIGNAL RATE, AND TRANSFER CONDITIONS ON VIGILANCE PERFORMANCE

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Subtask VIGIL IV

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INTRODUCTION

This report summarizes the procedures, results and conclusions for a series of studies on vigilance conducted at Fort Bliss, Texas during the period of January through June of 1961.

The general objective of Subtask VIGIL IV is to identify factors relevant to performance on a vigilance task and to develop methods and techniques for maintaining peak operator efficiency in vigilance situations. The specific purpose of the research is to demonstrate the relationship between a series of task and environmental factors and vigilance performance.

Background

An initial survey of the vigilance literature[1/] indicated that a job engineering approach to the problem of vigilance performance would have a reasonably high probability of success. The report discussed several hypotheses derived from theoretical considerations and cited empirical studies indicating four variables having consistently significant effects on vigilance performance. These latter included the effects of variations in signal rate, group vs. individual monitoring, the effects of interpolated rest periods, and the use of benzedrine.

1/ Bergum, B. O., & Klein, I. C. A Survey and Analysis of Vigilance Research. Research Report, HumRRO, 1961.

With the exception of the benzedrine variable, the studies conducted in this series were concerned with evaluation of the aforementioned factors. In addition, the final study in this series evaluated transfer effects between different signal rates.

Purpose

A total of seven studies were conducted. These included comparisons between multiple and single monitored systems; paired and isolated monitors at high and at low signal rates; spaced and massed monitoring at high and at low signal rates; a comparison of spaced, paired, and a combination of spaced and paired monitoring; and a comparison of transfer effects in going from high to low and from low to high signal rates in terms of two different displays.

The purpose of the first six studies in combination was to explore the influence of a task variable (signal rate) upon the output of multiple monitors and the relative efficiency of using interpolated rest with isolated monitors vs. continuous manning by paired and isolated monitors.

The purpose of the seventh study was to provide information concerning the feasibility of increasing monitoring efficiency for tasks involving low, or aperiodically fluctuating, signal rates by training in high, low, or both signal rates.

EXPERIMENT I

GROUP VS. INDIVIDUAL MONITORING

Introduction

The purpose of this study was to compare conditions of group monitoring with individual monitoring in a novel vigilance situation and to determine the extent to which vigilance performance is related to selected individual difference parameters.

Procedure

Subjects. Forty-two inexperienced National Guard trainees from the Army Training Center, Fort Bliss served as the subjects in this study. Except for the requirements that all individuals be between the ages of 18 and 26 years and have normal 20/20 vision (corrected), no effort was made to systematically select the individuals participating in the study.

Apparatus. Four isolation booths were employed in this study, each equipped with a circular panel, 13 in. in diameter, consisting of twenty 1/2 in. red lamps which illuminated in sequence at a rate of 12 rpm. A signal for this display consisted of the failure of a lamp to illuminate in its normal sequence. The displays were mounted vertically at seated eye height on the rear walls of the booths and a small table was located directly beneath the display and adjacent to the wall. The room was dimly illuminated by a shaded 40 watt frosted lamp mounted above and behind the subject.

A pre-set program (Mackworth schedule, 12 signals/1/2 hr.) caused a signal to be generated on the display and responses were made by depressing a hand-held pushbutton. Both signals and responses were automatically recorded on paper-tape recorders located in a central control area external to the booths. The control area and four booths were connected by a two-way intercom network.

Two response pushbuttons, each feeding to a separate recording channel, were located in one of the booths, and two pushbuttons leading to a single recording channel were located in a second booth. One pushbutton was located in each of the two remaining booths.

The experimental setup is illustrated in Fig. 1.

Conditions. All Ss worked continuously through three contiguous periods of approximately 30 min. each, for a total of approximately 90 min. of work without rest. The 42 Ss were randomly assigned to three groups of 14 Ss each. Group I, the control group, consisted of individuals working in isolation; Group II consisted of pairs of individuals working in the same booth, with freedom to converse about anything but the occurrence of failure signals; and Group III consisted of pairs of individuals working in the same booth with freedom to converse about anything including failure signals. Separate measures were taken on the individuals in the pairs in Group II, and a combined measure was taken for the pairs in Group III.

The response measures were frequency of correct detections and response latencies.

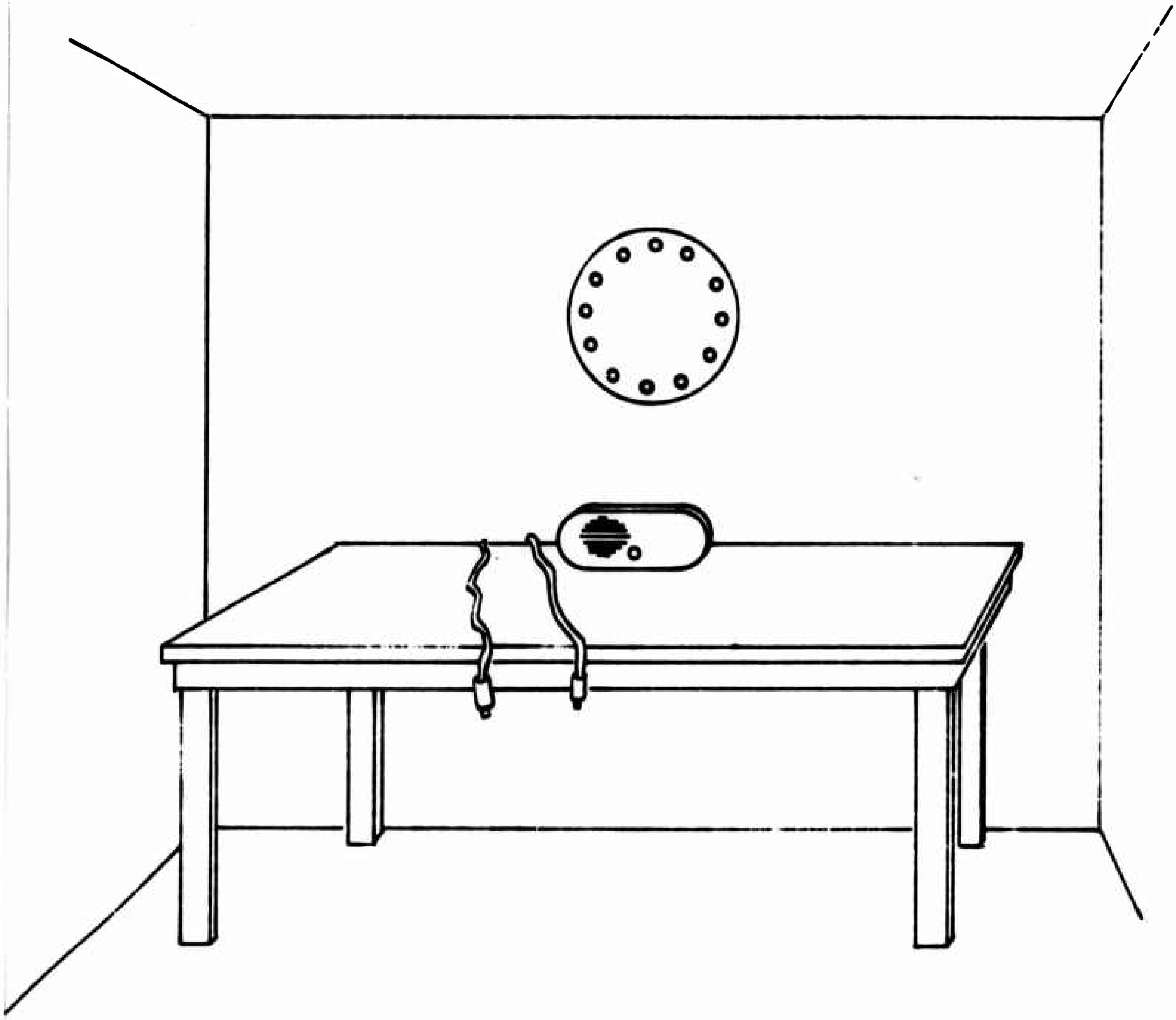

FIG. 1 LABORATORY VIGILANCE SETUP

Screening test. Prior to conduct of the experiment proper, all Ss were given four paper-and-pencil tests. The tests were administered in group form 24 hr. preceding their participation in the experiment proper. The tests included a "Letter Counting Test", a "Letter Comparison Test", a "Score Checking Test", and a "Clerical Carefulness Test".

Results

The results are considered first in terms of the correlations between the screening tests and detection scores. The second group of analyses are concerned with the effects of the experimental variables upon detection performance. The third group of analyses deal with the effects of the experimental variables upon response latencies.

Selection tests. Pearson product-moment correlations were computed between the individual screening test scores and the total detection scores for the individuals. Because the experimental variables resulted in mean differences between the groups, which in turn tended to confound the correlations because of the resulting bi-modal distribution of scores, the correlations were performed on the 14 individuals in the control group only. These correlations are presented in Table 1.

Of the four tests, two (Letter Comparison and Score Checking) yielded correlations approaching the 5% level of significance. In view of the small N and the exploratory nature of this study these r's appear to be sufficiently promising to warrant further exploration in future studies. The Letter Comparison Test yielded the highest r

TABLE 1

Correlations Between Detection Score and Screening Tests

TEST	r
Score Checking	-.402
Letter Comparison	-.487
Clerical Carefulness	-.222
Letter Counting	+.101

for the group ($r = .487$, $.10 > p > .05$) and required the least time for the *S*s to complete. In addition, this test yielded a relatively restricted range of scores. Because of this range restriction and the brief time required for administration, it would appear desirable to double or triple the length of the test. This would increase the reliability and variance of the test.

The *r*'s for the Clerical Carefulness and Letter Counting Tests are sufficiently low to suggest they would have little practical utility even should an increase in sample size demonstrate a true relationship to detection performance.

Detection performance. The detection scores were first analyzed in terms of the effect of group vs. individual monitoring. For this analysis, the scores for Groups II and III were pooled and the pairs of individuals treated as single individuals. Thus, for a given stimulus, the pair was scored a correct detection, but only one detection, if either one or both of the members of the pair made a correct detection. Group II thus yielded seven "individual" scores as did Group III. These 14 "individuals" or "systems" were compared with the 14 individuals or "systems" in Group I. The percentage of correct detections for the two groups and three time periods are presented in Fig. 2. An analysis of variance for this set of data is presented in Table 2.

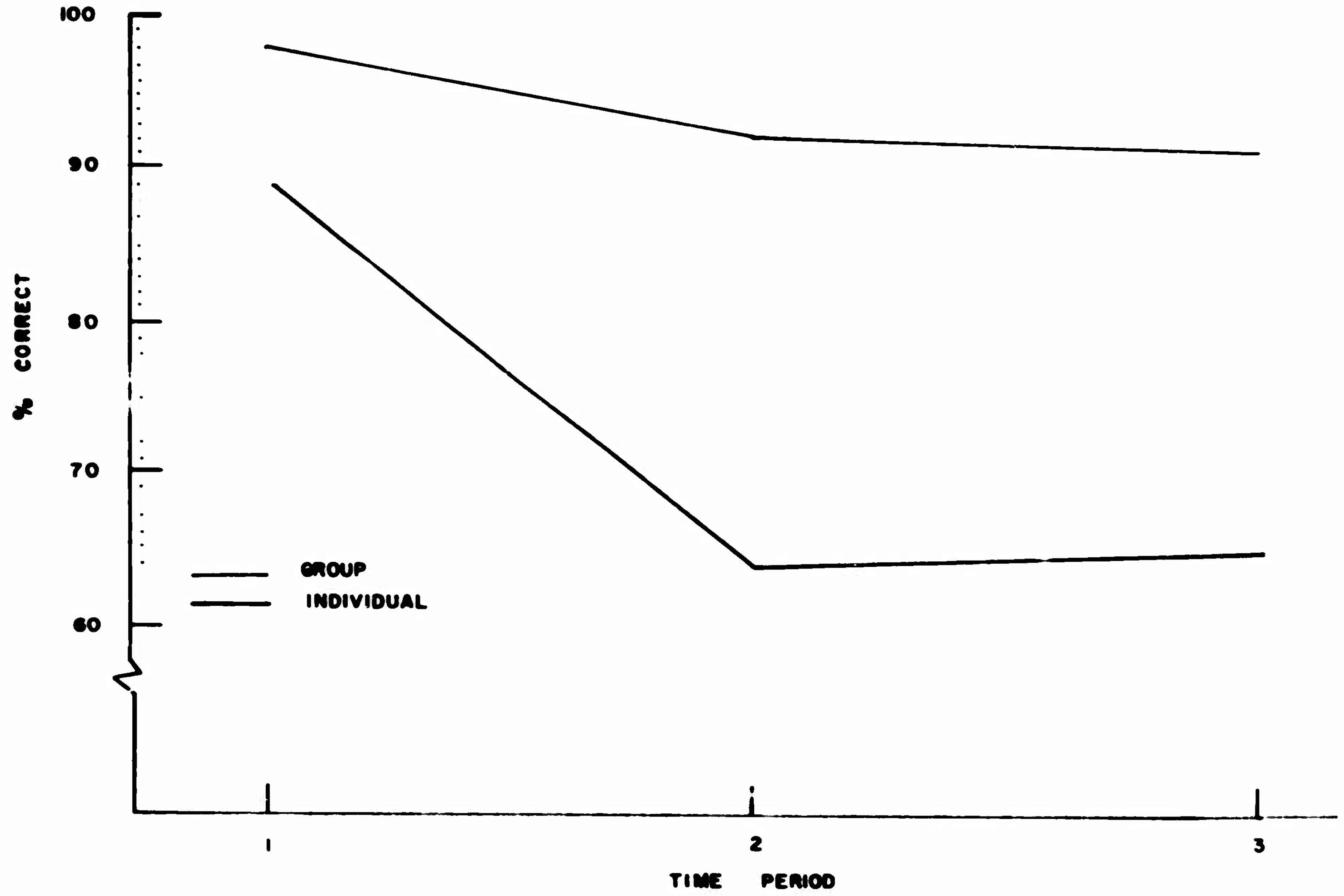

FIG 2 PERCENT CORRECT DETECTIONS FOR GROUP AND INDIVIDUAL MONITORS

TABLE 2

Analysis of Variance for Group and Individual Monitors

SOURCE	SS	df	MS	F	p
Group vs. Individual	136.30	1	136.30	7.92	<.01
S's same group	447.26	26	17.20		
	583.56	27			
Trials	61.30	2	30.96	9.14	<.01
Trials x Cond.	23.17	2	11.58	3.42	<.05
Pooled S's x Tr.	176.24	52	3.39		
	261.33	56			
	844.89	83			

The effect of double vs. individual monitoring was significant beyond the 1% level of confidence ($\underline{F}$ = 7.92, 1 & 26 $\underline{df}$), as was the effect of consecutive time periods ($\underline{F}$ = 9.14, 2 & 52 $\underline{df}$). In addition, the interaction between monitoring conditions and time periods was significant beyond the 5% level of confidence ($\underline{F}$ = 3.42, 2 & 52 $\underline{df}$).

A comparison between time periods for the two monitoring conditions yielded two significant $\underline{t}$'s. These differences, significant at the 1% level, were between the first and second, and first and third time periods for the group of individuals only. A comparison between the two monitoring groups at each of the three time periods, yielded $\underline{t}$'s significant at the 5% level for both the second and third time periods.

Double-monitoring resulted in no significant decrement in detection performance over the entire 90 min. test period, whereas the single monitors were detecting significantly fewer light failures by the end of the first 30 min. period and continued at this level through the remainder of the task. The performance of the individual monitors was slightly, but not significantly, poorer during the first time period, and was significantly poorer during the last two periods.

A second analysis was performed in terms of the 14 $\underline{S}$s making up the pairs in Group II, in this case treated as individuals, and the 14 $\underline{S}$s in Group I. The percentage of correct detections for the groups at each time period are given in Fig. 3. An analysis of variance for these data is presented in Table 3.

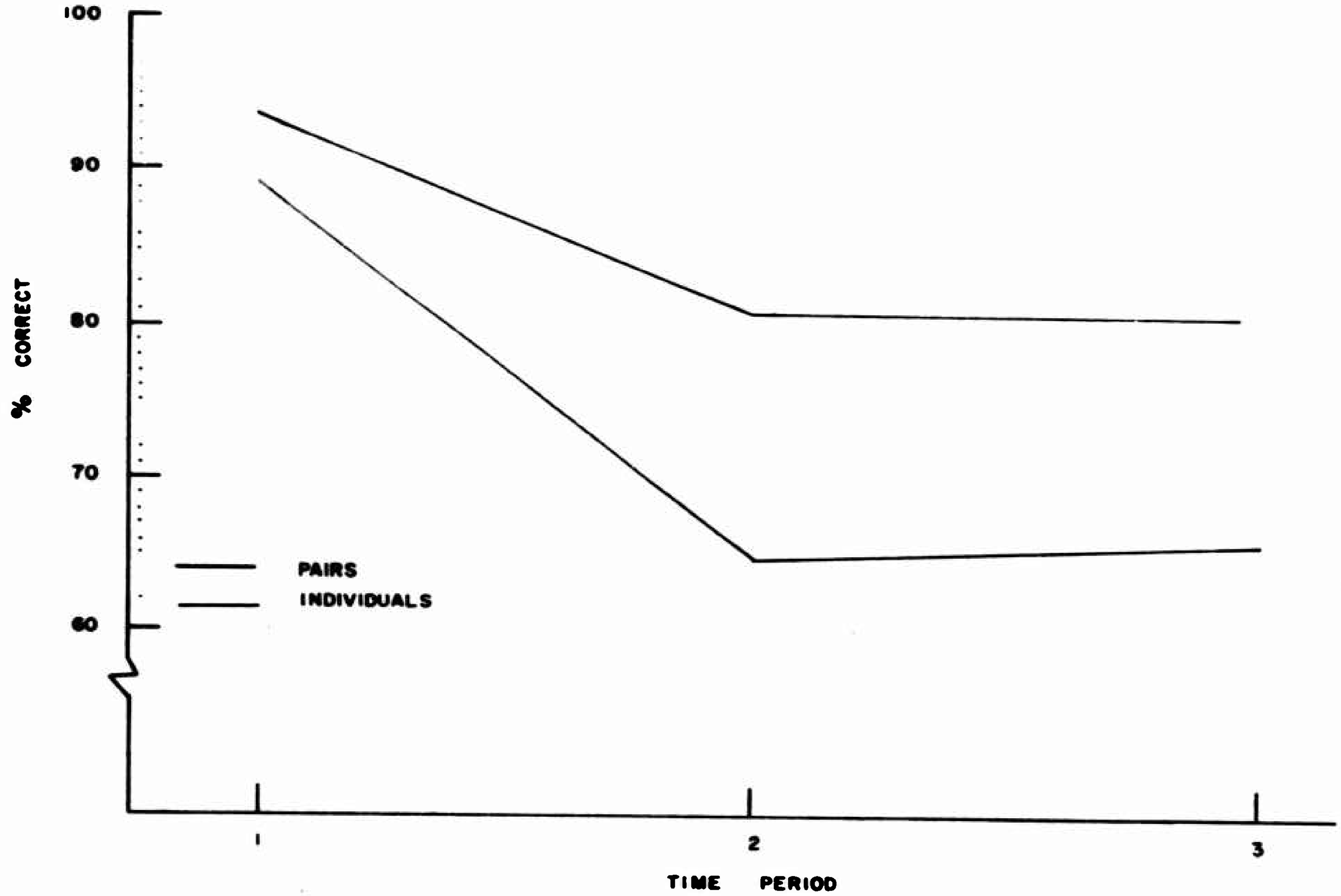

FIG. 3 PERCENT CORRECT DETECTIONS FOR MONITORS WORKING ALONE AND MONITORS WORKING IN PAIRS

TABLE 3

Analysis of Variance for Monitors Working Alone
and
Monitors Working in Pairs

SOURCE	SS	df	MS	F	p
Pairs vs. Indiv.	42.86	1	42.86	2.11	$.20 > p > .10$
S's in same group	528.64	26	20.33		
	571.50	27			
Trials	93.02	2	46.51	11.07	$< .005$
Tr. x Cond.	9.23	2	4.62		
Pooled S's x Tr.	218.49	52	4.20		
	320.74	56			
	892.24	83			

The *F* for monitors working alone as opposed to monitors working together is not significant ($F = 2.11$, 1 & 26 *df*, $.20 > p > .10$). The *F* for time periods is significant beyond the 1% level ($F = 11.07$, 2 & 52 *df*) while the interaction terms is non-significant.

A comparison between time periods for the two monitoring conditions yielded three significant *t*'s. For the monitors working alone, two differences significant at the 1% level were between the first and second, and first and third time periods. For the monitors working together a single difference, significant at the 5% level, was found between the first and third time periods.

Both groups of monitors showed significant decrements in detection performance. However, the decrement was generally less for the paired monitors and did not reach a significant level until the third period of work. The decrement for the isolated monitors was significant by the second period and continued at about the same level through the third period.

A final analysis was performed in terms of the three groups of 14 *Ss* each, with pairs of individuals treated as individuals. In the case of Groups II and III, the two monitors working together in the same booth were treated as a single individual. In the case of Group I, the scores for the two isolated monitors were combined and treated as a single score for randomly paired individuals. The analysis was thus based upon the scores for three groups of seven pairs of monitors. The percentages of correct detections by time periods for all groups are presented in Fig. 4. An analysis of variance for these data is given in Table 4. The *F*'s failed to approach acceptable levels of significance in all cases.

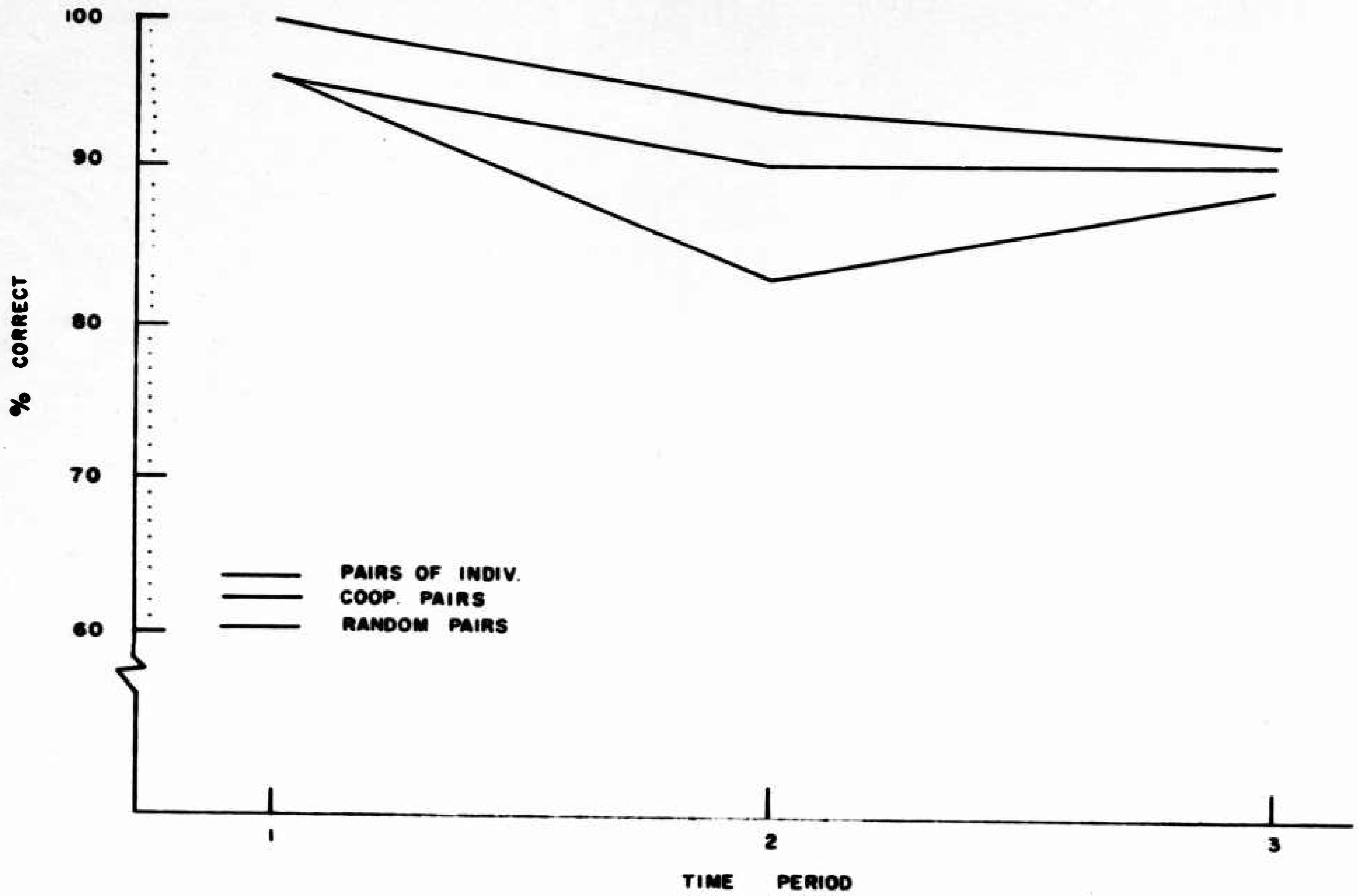

FIG. 4 PERCENT CORRECT DETECTIONS FOR THREE GROUPS OF PAIRS

TABLE 4

Analysis of Variance for Three Groups of Pairs

SOURCE	SS	df	MS	F
Pairs	5.37	2	2.68	0.44
S's same group	111.04	18	6.17	
	116.41	20		
Trials	9.93	2	4.97	2.01
Tr. x Cond.	2.44	4	0.61	0.31
Pooled S's x Tr.	88.96	36	2.47	
	101.34	42		
	217.74	62		

In the process of analyzing the data by traditional parametric techniques, it became apparent that the nature of the detection data was such that the effect of the experimental variables, when they were effective at all, was not only to increase the mean performance level but to reduce the variability of the responses. The dispersion of scores for the control Ss typically range from a few perfect performances through a few extremely poor performances, with very few individuals demonstrating the relatively smooth and systematic decrement displayed in the grouped data. The typical effect of an experimental variable is to considerably increase the number of perfect scores and eliminate most of the very poor scores. The net effect is reduced variability resulting from an asymmetrical (one-tailed) distribution of scores. In short, the effect of the experimental variable is to produce data which violate two fundamental assumptions of parametric statistics: normality, and homogeneity of variance. It is recognized that some latitude exists in the degree to which these assumptions may not be met without significantly effecting the validity of the statistical results, but in the present case it is not known whether the data exceed these tolerances or not. One solution to the problem would be to double the observed significance levels and interpret the data in these terms.

A second solution, however, would be to apply distribution-free statistics to the data as a check on the validity of the parametric findings. This was done for the analysis presented in the upper half

of Table 3. This particular analysis was selected because it was the only significant finding in the study relating to a primary variable.

The non-parametric tests were applied to the data. The first of these was the Mann-Whitney *U*-test. This test yielded a *U* of 42.5 with a *p* of less than .01 for a one-tailed test. The second non-parametric test was the Kruskal-Wallis one-way analysis of variance. This test yielded an *H* of 6.84 with a two-tailed *p* of less than .01. Both of these results are comparable to those obtained with the parametric *F*-test. Of the two non-parametrics, however, the Kruskal-Wallis test appears to be slightly more powerful for this type of data.

Latencies. Mean latencies for each individual in Groups I and II for each time period were computed. In two cases individuals failed to respond during a time period and their mean latencies (in arbitrary units) for the preceding period were substituted in the data. These means are presented in Table 5. Because they do not display the special characteristics of the detection data, an analysis of variance was performed on these data and the results are presented in Table 6.

None of the *F*'s were significant in this analysis. However, all *F*'s fell between the 10% and 20% levels of confidence. These results are of some interest in that they suggest that individuals working alone demonstrate relatively long and relatively constant latencies throughout the test period, while the latencies for pairs of individuals start out relatively short and increase to a level equal to that of the lone workers by the end of testing. While not

TABLE 5

Response Latencies* for Monitors Working in Pairs and Alone

TIME PERIOD

CONDITION	1	2	3	AVERAGE
Pairs	3.67	3.94	4.21	3.94
Individuals	4.21	4.29	4.19	4.23
Average	3.94	4.11	4.20	

*In Arbitrary units: one unit equals 0.40 sec. approximately.

TABLE 6

Analysis of Variance for Response Latencies
for Monitors Working in Pairs and Alone

SOURCE	SS	df	MS	F	p
Pairs vs. Indiv.	2.38	1	2.38	1.85	$.20 > p > .10$
S's same group	33.68	26	1.29		
	36.06	27			
Trials	1.60	2	0.30	1.89	$.20 > p > .10$
Tr. x Cond.	0.63	2	0.32	1.99	$.20 > p > .10$
Pooled S's x Tr.	8.26	52	0.16		
	9.49	56			
	45.55				

significant, these results suggest a possible adaptation effect to the stimulation deriving from the presence of another monitor.

Discussion

The near-significant correlations between two of the paper-and-pencil screening tests, despite the relatively small sample size, is encouraging and suggests that such devices may prove useful in the prediction of monitoring behavior. In particular, as suggested earlier, it is quite possible that an increase in length for the "Letter Comparison Test" might increase its effectiveness. Both this and the "Score Checking Test" show sufficient promise to warrant further investigation in future studies.

The highly significant differences between isolated monitors and paired monitors working independently was to be anticipated on a simple statistical basis. This notion is supported by the relatively high level of detection performance for the "paired" individuals in Group I as compared with their performance when treated as individuals in the final detection score analysis. Of considerable theoretical interest, however, was the tendency in the analyses for the isolated monitors to perform at a lower level than monitors working in pairs. If the effects of pairing were no more than the additive effects of overlapping distributions of individual detections the pairs of monitors working together should have been no better than the monitors working alone. Thus, had the comparison between the 14 Ss in Group I with the 14 Ss in Group II attained significance, a "statistical" hypothesis (in which the combined probability of detection for the paired Ss would be the

predicted performance level) could have been rejected and an "activation" hypothesis (in which the predicted performance level would be significantly higher than that predicted by the statistical hypothesis) supported. If it could be assumed that a larger sample would demonstrate this to be a true difference, this finding would have implications for "real world" monitoring situations and appears worthy of further study.

As noted in the Results section, the latency data tend also to support an activation hypothesis interpretation of the data although, again, the results fall short of statistical significance. A Pearson product-moment correlation between latencies and detection scores indicated no relationship between these measures ($r = -.080$) and this independence lends further weight to an activation interpretation, i.e.: two independent measures, while statistically non-significant in their effects with a limited sample, both tend to support the notion that some factor is present in group monitoring which tends to push performance above a simple statistically predictable facilitation of performance.

EXPERIMENT II

EFFECTS OF PAIRING ON INDIVIDUAL PERFORMANCE (HIGH SIGNAL RATE)

Introduction

The purpose of this study was to explore further the suggestive effects of pairing on individual performance found in Experiment I of this series. In the first study a comparison was made between the individual performances of monitors working in pairs and monitors working alone. The results suggested that individual monitoring performances were improved when one monitor worked in the presence of another monitor, but this difference was not statistically reliable.

This result is of both practical and theoretical interest. In the practical case, given a decision to employ more than one monitor in the system, the further decision to employ one or two displays in the same or different physical locations in the system could reasonably be affected by the possible facilitating effect of the immediate presence of another monitor.

From a theoretical point of view, this result is of interest in that it is in the direction predicted by an activation hypothesis, and should the result be replicable, would constitute further supportive evidence for a general activation interpretation of vigilance behavior.

Procedure

Subjects. A total of 40 inexperienced National Guard trainees from the Army Training Center, Fort Bliss, served as the subjects in this study. The requirements were similar to those in Experiment I.

Apparatus. The apparatus employed in this study was identical to that used in Experiment I.

Conditions. All Ss worked continuously through three contiguous periods of approximately 30 min. each, for a total of approximately 90 min. of work without rest. The 40 Ss were randomly assigned to two groups of 20 Ss each. Group I, the control group, consisted of individuals working in isolation; Group II consisted of pairs of individuals working independently in the same booth with freedom to converse about anything but the occurrence of failure signals. Separate measures were taken on all individuals in both groups. Signal rate was 24 signals/hr.

The response measures were frequency of correct detections and response latencies.

Results

The first set of analyses is concerned with detection scores. Included in these analyses are a comparison of the major groups and correlations between pairs of individuals in the same groups. The second set of analyses deal with the effects of the experimental variable upon response latencies.

Detection performance. Figure 5 presents the mean percentage detection scores for the two groups for each of the three half-hour work periods. Both groups showed a decline in performance over time, but the mean performance of the paired individuals tended to be superior over all. A Kruskall-Wallis one-way analysis of variance was performed on these data to determine the significance of these group differences.

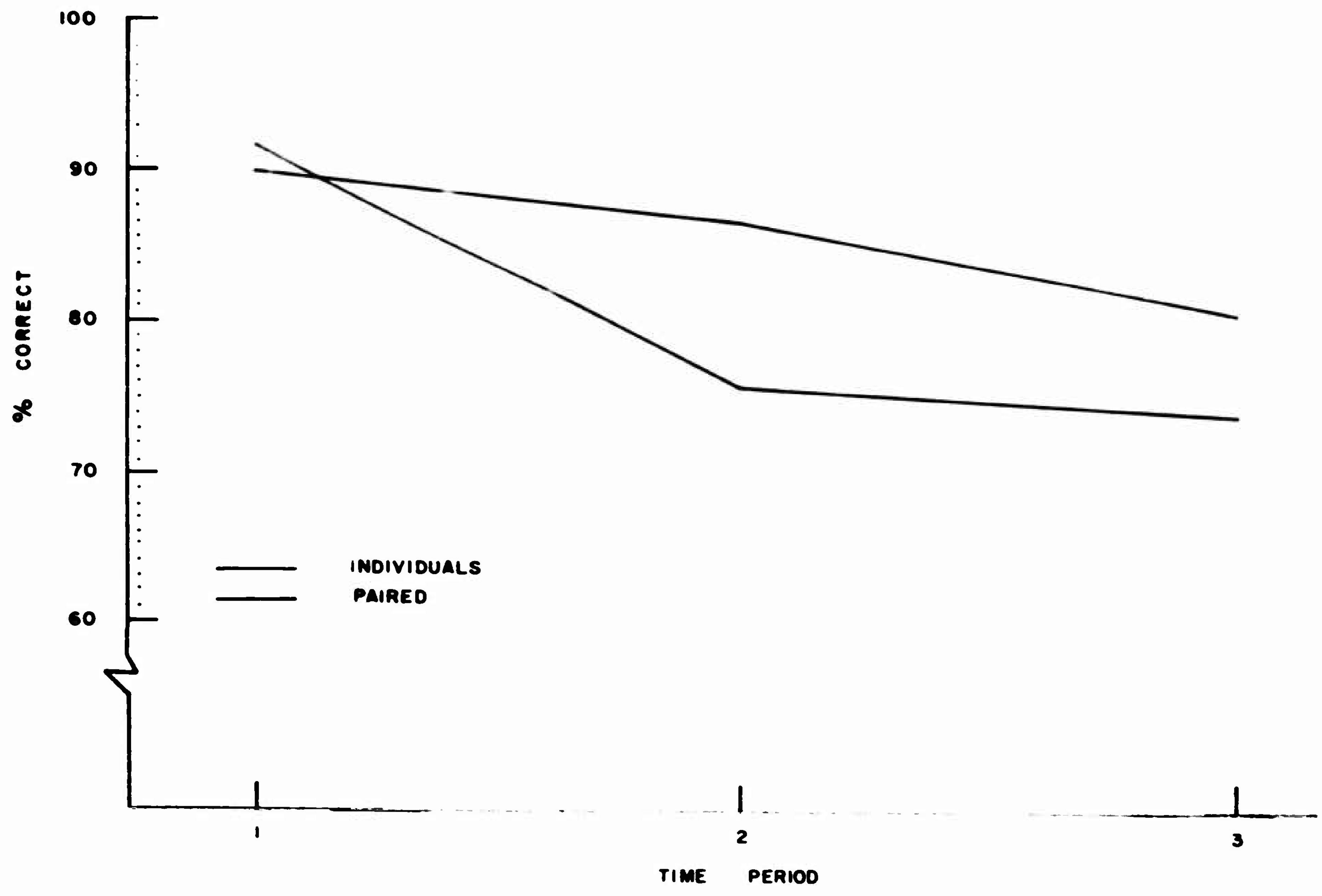

FIG. 5 PERCENT CORRECT DETECTIONS FOR PAIRED AND ISOLATED MONITORS

This analysis yielded an $\underline{H}$ of 1.38 with an associated two-tailed probability of $.20 > \underline{p} > .10$. This is precisely the same result obtained in Experiment I for this comparison and suggests strongly that pairing does tend to increase individual performances but is a relatively minor variable.

In order to determine the specificity of the pairing effect on performance, a rank order correlation was performed between the members of the 10 pairs of individuals working together. This analysis yielded a rho of .709, $\underline{p} < .05$. As a control for this analysis, a second rho was computed between individuals tested at the same time but in separate booths. This analysis yielded a rho of .109, $\underline{p} > .05$. Finally, the detection scores for the two paired individuals were combined and paired with the combined scores of the two individuals in separate booths for a given session. This yielded 10 pairs of scores for which a final rank order correlation was performed. The purpose of this analysis was to determine whether common factors were affecting the performance of all Ss in a given session which might account for the significant rho between paired individuals. This analysis yielded a rho of -.082, $\underline{p} > .05$. These analyses suggest that, whatever the effect of pairing, it tended to be specific to a given pair of individuals, i.e., when one member of the pair did well, the other member also did well and these results cannot be accounted for by test situation artifacts.

Latencies. Mean response latencies (arbitrary units) for each group for each of the three test periods were computed and are presented in Table 7. The pairs tended to respond at a constant more rapid rate

TABLE 7

Response Latencies* for Individuals Working in Pairs and Alone

TIME PERIOD

CONDITION	1	2	3	AVERAGE
PAIRED	3.34	3.37	3.33	3.35
INDIVIDUALS	3.43	3.73	3.71	3.62
AVERAGE	3.39	3.55	3.52	

*In arbitrary units: one unit equals 0.40 sec. approximately.

throughout all sessions than did the individuals, who tended to respond rapidly in the first period and more slowly in the final two periods. An analysis of variance of these data, however, yielded no significant F's for any of the comparisons.

Discussion

The results of this study, in terms of the significant correlations between the performances of the paired individuals, tend to support the interpretation that a significant interaction occurs between the paired individuals. It is probable that the statistically non-significant superiority of pairs over the random combination of individuals found in both studies is nonetheless a real effect in view of the present finding, i.e., something is happening as a result of the pairing of monitors in the same environment over and above what could be expected by a simple statistical combination of their responses.

What this "something" is cannot immediately be determined from the data. The analyses indicate that it is not an artifact of the apparatus or procedures and, because the Ss knew they were being monitored over the intercom, it is improbable that the effect was the result of cheating between the members of the pairs.

The overall results are in line with what would be predicted from an activation hypothesis interpretation in that the presence of another individual would tend to increase the general stimulation level in the environment and thus facilitate the general level of alertness of the individuals participating. However, this interpretation does not

explain why the effect is specific to the pairs, i.e., why a correlation exists between the members of the pairs. A strict activation interpretation would require a general facilitation of performance for the paired individuals, but no relationship between pairs of individual scores. Thus, activation may explain part of the effect, but certainly not all of the effect.

EXPERIMENT III

EFFECTS OF PAIRING ON INDIVIDUAL PERFORMANCE (LOW SIGNAL RATE)

Introduction

In the preceding experiments a facilitating effect as a result of pairing monitors was demonstrated when a high signal rate (24 signals/hr.) was employed. The purpose of this study was to determine whether a similar facilitating effect could be demonstrated when a low signal rate (6 signals/hr.) was employed.

Procedure

Subjects. A total of 40 inexperienced National Guard trainees from the Army Training Center, Fort Bliss served as the subjects in this study. The subject requirements were similar to those employed in the preceding two studies.

Apparatus. The apparatus employed in this study was identical to that employed in the preceding two studies.

Conditions. All Ss worked continuously through three contiguous periods of approximately 30 min. each, for a total of 90 min. of work without rest. The 40 Ss were randomly assigned to two groups of 20 Ss each. Group I, the control group, consisted of individuals working alone in separate booths; Group II consisted of pairs of individuals working in the same booth with freedom to converse about anything but the occurrence of failure signals. Separate measures were taken on all individuals

in both groups. The response measures were frequency of correct detections and response latencies. The signal rate was 6 signals/hr.

Results

Two groups of analyses were performed on the data. The first group was in terms of detection scores; the second was in terms of response latencies.

Detection performance. The mean percentage of correct detections for both groups for each of the three test periods is presented in Fig. 6. Both groups showed a decrement in performance over time, with neither group showing any marked superiority over the other. A Kruskal-Wallis one-way analysis of variance yielded an H of .15 with an associated one-tailed p of $> .05$. In contrast to the results obtained under high signal rate conditions, pairing does not appear to have had a facilitating effect upon overall detection performance when signal rate is low.

In order to determine whether the pairing variable continued to result in a significant interaction between individuals working together despite the failure to obtain an overall effect, a rank order correlation was performed between the members of the 10 pairs of individuals working together. This analysis yielded a rho of .773, $p < .01$. As a control, a second rho was computed between individuals tested at the same time but in separate booths. This analysis yielded a rho of - .152,

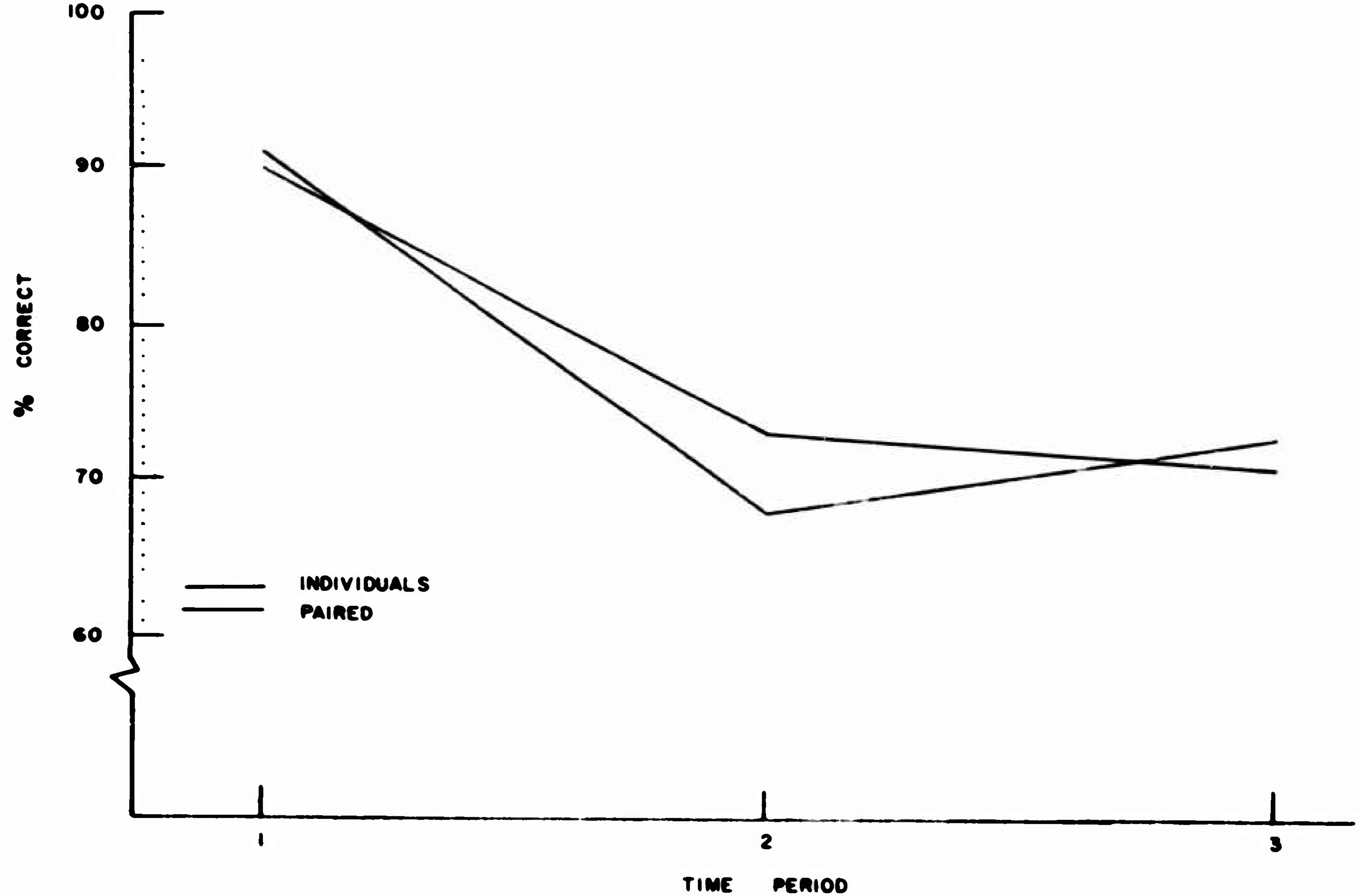

FIG. 6 PERCENT CORRECT DETECTIONS FOR PAIRED AND ISOLATED MONITORS

$p > .05$. A *rho* betweenn the combined scores for paired individuals and the combined scores for the individuals in separate booths for a given session was also computed. The value of this *rho* was .115, $p > .05$. These results are very similar to those found in Experiment II and tend to further confirm the conclusion that the effects of pairing are specific to the individuals involved.

Latencies. The mean response latencies (arbitrary units) for both groups at each time period are presented in Table 8. The pairs tended to respond more rapidly as time progressed, while the individuals tended to respond more slowly as time progressed. As was the case in the earlier studies, the overall latencies for the paired *S*s tended to be superior to those for the individuals. Also as before, an analysis of variance of these data failed to yield any significant *F*'s.

Discussion

The failure of the pairing variable to effect the overall detection efficiency was quite unexpected and lends weight to the argument that the effect is rather specific to the pairs of individuals involved. The highly significant correlation between the performances of the paired individuals lends further support to this notion and provides further evidence contrary to the interpretation that cheating might account for the pairing effect. If signal information were being exchanged the effect would be to raise the overall detection performance for the group and this did not occur.

TABLE 8

Response Latencies* for Individuals Working in Pairs and Alone

TIME PERIOD

CONDITION	1	2	3	AVERAGE
Individuals	3.78	4.08	4.40	4.09
Paired	3.86	3.79	3.66	3.77
AVERAGE	3.82	3.94	4.03	

*In arbitrary units: one unit equals 0.40 sec. approximately.

A possible interpretation of the results that would still be in line with an activation interpretation might be that the effects of environmental stimulation are conditional upon the degree of stimulation. Thus, for example, when stimulation was relatively mild its effect might be facilitative. Beyond some point, however, irrelevant stimulation (intensive conversation, for example) might be distracting and interfere with performance. While the information was not recorded and not correlated with performance, it was apparent in monitoring the conversations of the paired Ss that considerable variation occurred among the pairs in terms both of the amount and intensity of conversation.

EXPERIMENT IV

EFFECTS OF REST PERIODS ON PERFORMANCE (HIGH SIGNAL RATE)

Introduction

The purpose of this study was to determine the effects of brief rest periods upon individual monitoring performance on a task employing a high (24 signals/hr.) signal rate.

Procedure

Subjects. A total of 40 inexperienced National Guard trainees from the Army Training Center, Fort Bliss served as the subjects in this study. The requirements were similar to those in the preceding three studies.

Apparatus. The apparatus employed in this study was identical to that employed in the preceding studies.

Conditions. All Ss worked in isolation through three periods of approximately 30 min. each, for a total of 90 min. of monitoring. The 40 Ss were randomly assigned to two groups of 20 Ss each. Group I Ss worked continuously through the 90 min. period, while Group II Ss were permitted a 10 min. rest period outside the test cubicles between the first and second, and second and third, monitoring periods.

The light failure sequence was identical for all Ss in both conditions during all monitoring sessions and was at a rate of 24 signals/hr. Independent measures of correct detections and response latencies were taken for all Ss.

Results

The data were analyzed first in terms of number of correct detections and then in terms of response latencies.

Detection performance. The mean percentage of correct detections for both groups for each of the three test periods are presented in Fig. 7. The rest condition shows an almost constant high level of performance (approximately 95% correct detections) over the entire testing session, while the massed condition shows a marked and continuing performance decrement with progressive work periods.

A Kruskal-Wallis one-way analysis of variance for these data yielded an H of 5.44 with an associated one-tailed p of less than .01. Brief rest periods resulted in significantly superior detection performance.

Latencies. The mean response latencies (arbitrary units) for both groups at each time period are presented in Table 9. The spaced group showed no consistent trend, but tended to perform more rapidly in general than the massed group. The massed group tended to perform slightly better in the initial than in the remaining two periods. An analysis of variance for these data yielded no significant F's.

Discussion

The results for the detection data are quite clear cut. The introduction of rest intervals results in significantly superior detection performance over the entire monitoring period used in this study. These results were as expected and are of interest primarily because they

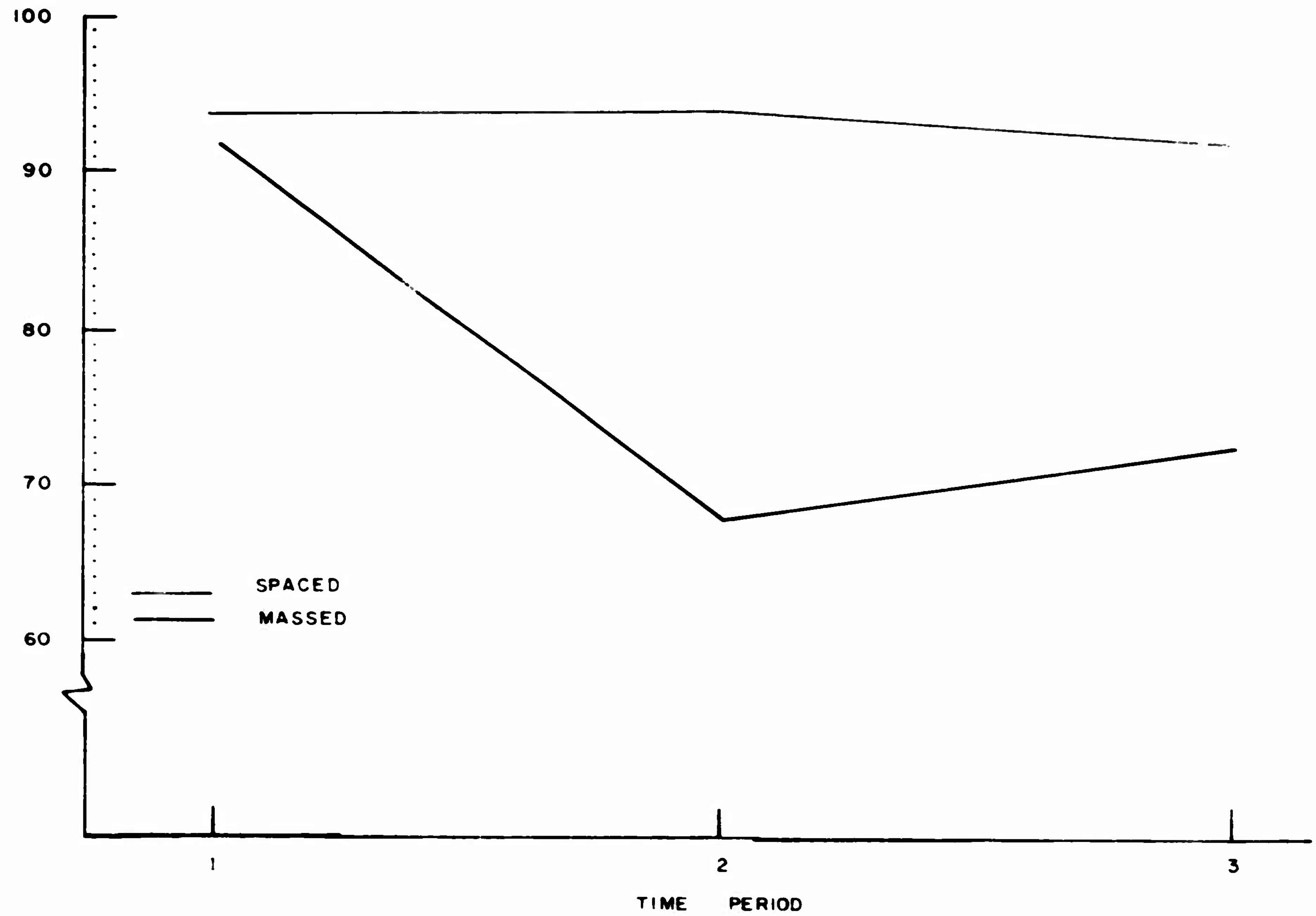

FIG. 7 PERCENT CORRECT DETECTIONS FOR SPACED AND MASSED MONITORS

TABLE 9

Response Latencies* for Spaced and Massed Monitors

TIME PERIOD

CONDITION	1	2	3	AVERAGE
Spaced	3.38	3.44	3.31	3.38
Massed	3.43	3.73	3.71	3.62
AVERAGE	3.41	3.59	3.51	

*In arbitrary units: one unit equals 0.40 sec. approximately.

demonstrate the effectiveness of this variable even when the length of the rest pause amounts to about one quarter of the total work period. Earlier studies employing this variable (Mackworth) demonstrated its effectiveness under conditions in which time off was equal to time on the job, but the present results suggest that rest periods of even briefer duration than those employed in the present study may be equally effective in maintaining a high level of performance.

EXPERIMENT V

EFFECTS OF REST PERIODS ON PERFORMANCE (LOW SIGNAL RATE)

Introduction

The purpose of this study was to determine the effects of brief rest periods upon individual monitoring performance on a task employing a low (6 signals/hr.) signal rate.

Procedure

Subjects. A total of 20 inexperienced National Guard trainees from the Army Training Center, Fort Bliss served as the subjects in this study. The requirements were similar to those in the preceding four studies.

Apparatus. The apparatus employed in this study was identical to that employed in the preceding studies.

Conditions. The conditions for this experiment were identical to those employed in the preceding study (Experiment IV) with the exception that the signal rate was 6 signals/hr. rather than 24 signals/hr.

Results

The data were analyzed first in terms of number of correct detections and finally in terms of response latencies.

Detection performance. The mean percentage of correct detections for both groups for each of the three test periods are presented in Fig. 8. The results are similar to those obtained in Experiment IV employing a high signal rate. The rest condition shows an almost

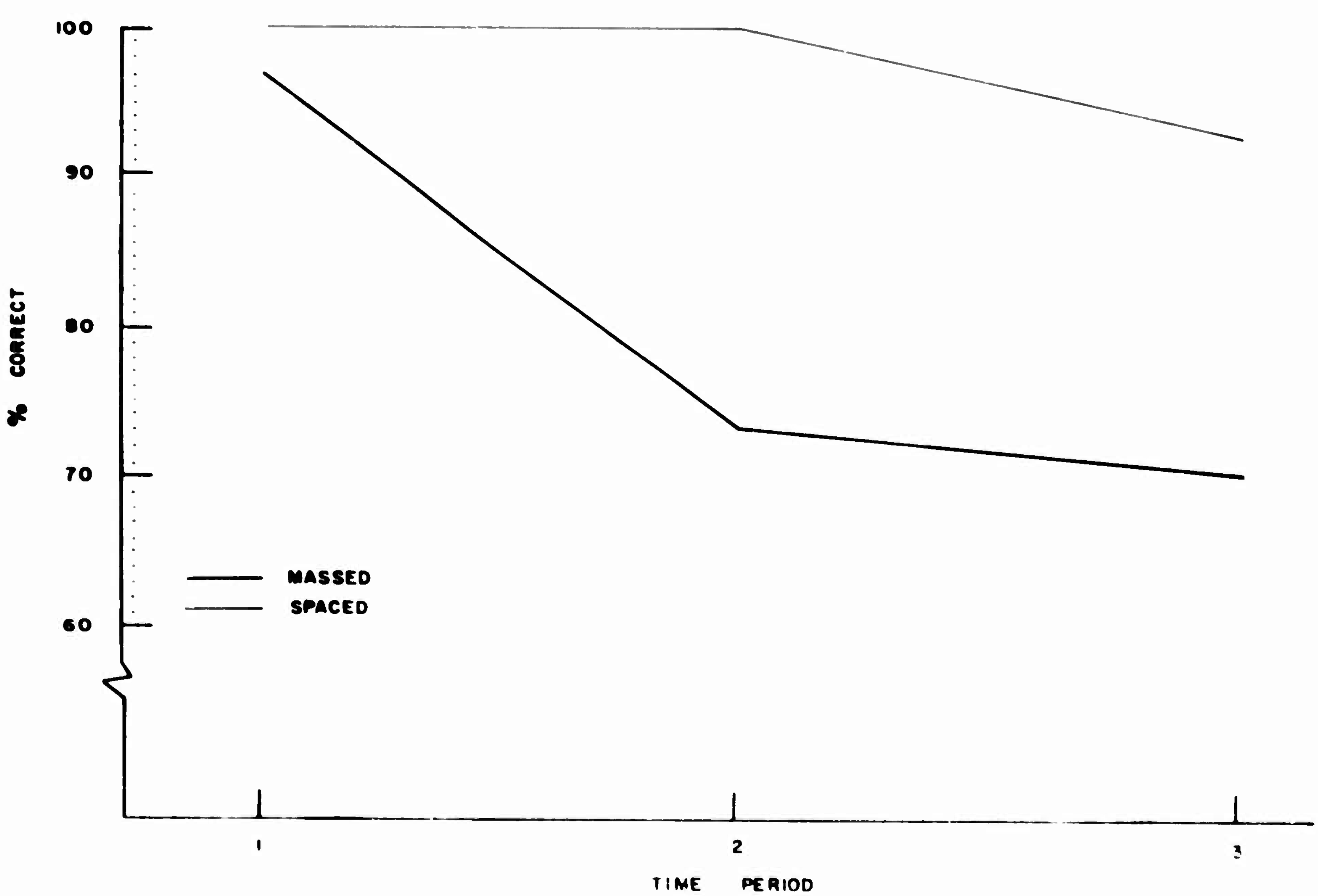

FIG 8 PERCENT CORRECT DETECTIONS FOR SPACED AND MASSED MONITORS

constant high level of performance over the full testing period, while the massed condition shows a marked performance decrement with progressive work periods.

A Kruskal-Wallis one-way analysis of variance for these data yielded an $\underline{H}$ of 4.73 with an associated one-tailed $\underline{p}$ of less than .025. As was the case in Experiment IV, brief rest periods resulted in superior detection performance.

Latencies. The mean response latencies (arbitrary units) for both groups at each time period are presented in Table 10. In terms of overall latencies there does not appear to be any difference between massing and spacing. In the initial period the massed group appears to perform quite slowly and improves in the final two periods. In contrast, the spaced group tended to respond rapidly in the first period and then level off at a lower level during the remaining two periods.

An analysis of variance for these data is presented in Table 11. The only significant $\underline{F}$ in this analysis was for the conditions just described: between sessions and conditions ($\underline{p} < .05$). The reason for this interaction effect is not apparent.

Discussion

The principal significance of the present results lies in the fact that they are almost identical to those found when spacing was employed with a high signal rate. These results further confirm the power and generality of this variable in its effects upon monitoring performance.

TABLE 10

Response Latencies* for Massed and Spaced Monitors

TIME PERIOD

CONDITION	1	2	3	AVERAGE
Massed	2.31	1.55	1.59	1.82
Spaced	1.65	1.97	1.93	1.85
AVERAGE	1.98	1.76	1.76	

*In arbitrary units: one unit equals 1.25 sec. approximately.

TABLE 11

Analysis of Variance for Massed vs. Spaced Monitoring over Three Time Periods

SOURCE	SS	df	MS	F
Mass vs. Space	.02	1	.02	-
Between Ss	12.14	18	.67	
TOTAL	12.16	19		
Between Sessions	.65	2	.325	-
Session x Cond.	3.59	2	1.800	4.99*
Pooled Ss x Sess.	12.98	36	.361	
TOTAL WITHIN	17.22	40		
TOTAL	29.38			

* $p < .05$

EXPERIMENT VI

COMPARATIVE EFFECTS OF PAIRING, REST PERIODS, AND A COMBINATION OF PAIRING AND REST PERIODS

Introduction

The purpose of this study was to compare the relative effects of pairing, rest pauses, and a combination of pairing and rest pauses. It was predicted that a combination of these conditions would be superior to either condition alone.

Procedure

Subjects. A total of 60 inexperienced National Guard trainees from the Army Training Center, Fort Bliss served as the subjects in this study. The requirements were similar to those in the preceding experiments.

Apparatus. The apparatus employed in this study was identical to that used in the preceding five studies.

Conditions. All Ss worked through three periods of approximately 30 min. each, for a total of approximately 90 min. of work. The 60 Ss were randomly assigned to three groups of 20 Ss each. Group I consisted of pairs of individuals working in the same booth with freedom to converse about anything but the occurrence of failure signals. These Ss worked continuously through the 90 min. period. Group II consisted of individuals working in isolation. These Ss were permitted a 10 min.

rest pause outside the test cubicles between the first and second, and second and third, monitoring periods. In group III, Ss worked in pairs and received a 10 min. rest pause between the first and second, and second and third, monitoring periods.

The light failure sequence was identical for all Ss in all conditions during all monitoring periods and was at a rate of 24 signals/hr. Independent measures of correct detections were taken for all Ss.

Results

The mean percentage of correct detections for all groups for each of the three monitoring periods are presented in Fig. 9. As predicted, the combination of pairing and rest pauses yielded the highest overall performance, with rest pauses and pairing following in that order.

In order to test the overall significance of these differences a Kruskal-Wallis one-way analysis of variance was applied to these data. This analysis yielded an H of 3.24 with an associated p of between .10 and .20 for 2 df. Because of the relatively low significance level of this finding, no further analyses were made of the data.

Discussion

The results of this study, while statistically non-significant, were in the predicted direction. The reason for this failure to obtain

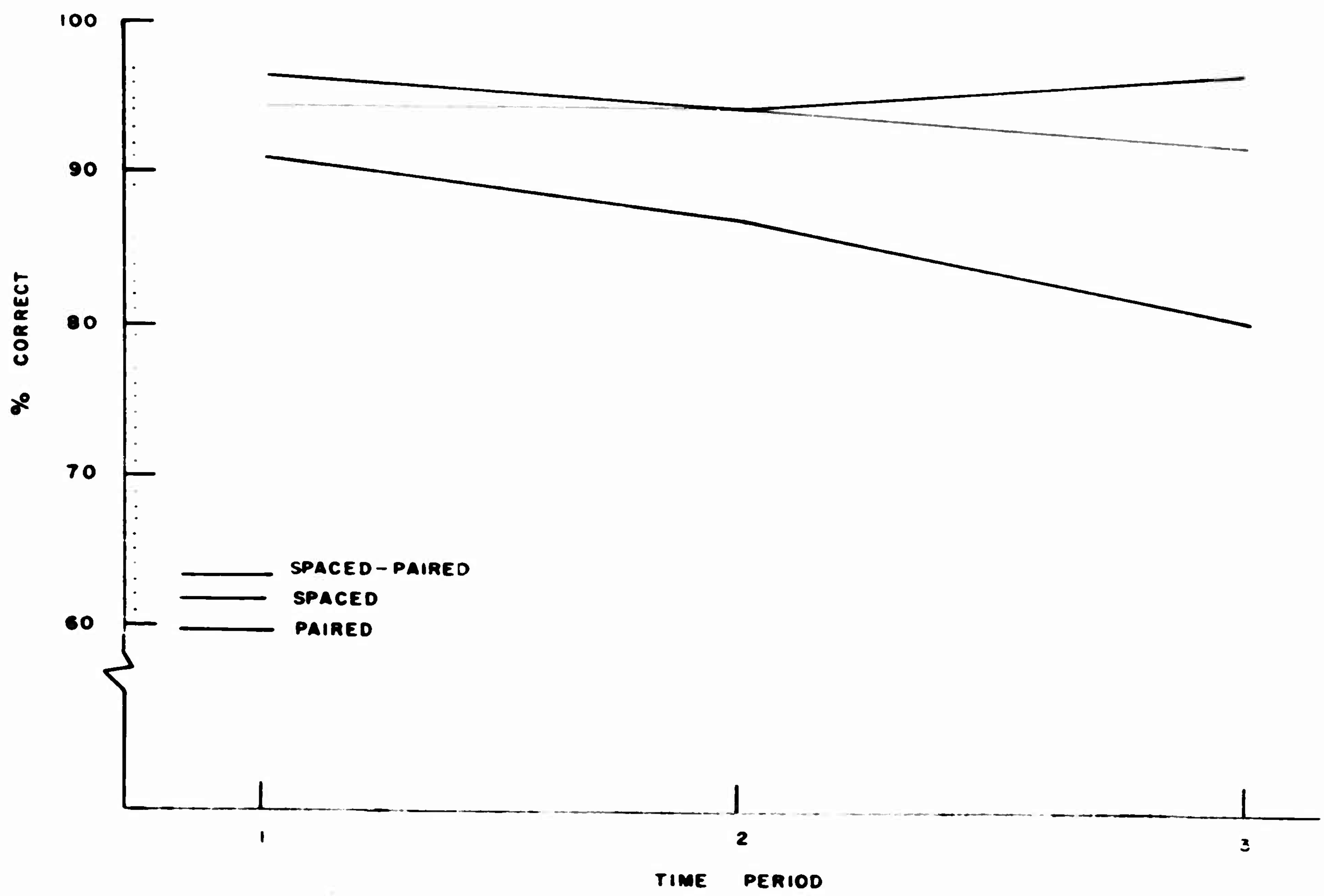

FIG 9 PERCENT CORRECT DETECTIONS FOR SPACED, PAIRED, AND SPACED - PAIRED MONITORS

significant differences is apparent when the generally high level of performance for all groups is considered. The nature of the data is such that the range of possible improvement is arbitrarily restricted by an absolute maximum number of detections. The effect of this restriction is to create a relatively insensitive test of the effects of the different variables and their combinations.

From a practical point of view, however, this restriction of variability is both significant and desirable since the objective is to reduce variability to zero. These results suggest that a combination of more than two effective variables would probably add little to this objective.

EXPERIMENT VII

TRANSFER BETWEEN SIGNAL RATES

Introduction

The purpose of this study was to determine the effects upon subsequent performance at a given signal rate of initial performance on a vigilance task at a different signal rate. A second purpose was to determine the extent to which vigilance performance is comparable between two qualitatively different display systems. It was anticipated that this study would yield information relative to the feasibility of increasing monitoring efficiency for tasks involving low, or aperiodically fluctuating, signal rates by training in high, low, or both signal rates as these apply to different display systems.

Procedure

Subjects. A total of 80 inexperienced National Guard trainees from the Army Training Center, Fort Bliss, served as the subjects in this study. The requirements were similar to those in the preceding studies.

Apparatus. With the exceptions to be noted, the apparatus was identical to that employed in the earlier studies in this series, including the four booths, the circular light panels, and the intercom network. In the present study all booths had only one pushbutton.

In addition, two of the booths were each equipped with a null-meter display. This display consists of an ammeter with a pointer centered at zero which can vary through an angular range of approximately 20 degrees on either side of zero. Except when a signal is generated by the programmer, the pointer remains relatively stable about the zero point on the dial face. Generation of a signal results in a clockwise deflection of the pointer through approximately 15 degrees of rotation. Signals for both the null-meter and light displays were simultaneously generated by the same programmer.

Conditions. The design of the experiment included combinations of two transfer conditions with two display conditions. The Ss in Condition I performed first at a signal rate of 24 signals/hr. and were transferred in a second session to a rate of 6 signals/hr. The Ss in Condition II performed first at a signal rate of 6 signals/hr. and were transferred in a second session to a rate of 24 signals/hr. Half of the Ss in both conditions worked with the light display, and the remaining half worked with the null-meter display.

The 80 Ss were randomly assigned to the four conditions of transfer and display, with a total of 20 Ss in each group.

All Ss monitored through two periods of 45 min. each, with a period of approximately 50 min. of rest between the two monitoring sessions. Ss rested outside the experimental booths.

Results.

The detection data were analyzed first in terms of type of display. Following this a series of separate analyses were performed first on the meter data and then on the light data. The final analyses were on the response latency data.

Displays. The mean percentage of correct detections for the meter display was 94.9% as opposed to a mean percentage of 82.2% for the light display. A Mann-Whitney test of these data yielded a large-sample Z of 4.75 with a p of less than .0003 and it was concluded that the two groups represented samples from two different populations. In view of this result the data from the lights and meters were treated as two separate experiments.

Null-meters. The first analysis consisted of a comparison of the performance at the high signal rate of the 20 *Ss* whose initial performance was at the high signal rate with the performance of the 20 *Ss* whose initial performance was at the low signal rate. The purpose of this analysis was to determine the transfer effects in going from a low to a high signal rate. The mean percentage correct detections for these groups were 92.2% for the control group and 97.8% for the transfer group.

A Krushak-Wallis one-way analysis of variance yielded an H of 1.23 with a p greater than .05. There was no significant transfer in going from the low to the high signal rate.

The second analysis consisted of a comparison of the performance at the low signal rate of the 20 Ss whose initial performance was at the low signal rate with the performance of the 20 Ss whose initial performance was at the high signal rate. The purpose of this analysis was to determine the transfer effects in going from a high to a low signal rate. The mean percentage correct detections for these groups were 96% for the control group and 93% for the transfer group.

A Kruskal-Wallis one-way analysis of variance yielded an H of 0.128 with a p greater than .05. There was no significant transfer in going from high to low signal rates.

The final analysis consisted of a comparison between performance at the high signal rate with performance at the low signal rate regardless of which order the individual participated in these conditions. This analysis was possible because of the failure to find transfer effects between signal rates.

The mean percentage correct detections for the high signal rate was 95%; the mean for the low signal rate was 94%. A Wilcoxon matched-pairs signed-ranks test on these data yielded a T of 38 with an associated p greater than .05. In this case no significant difference as a function of signal rate was demonstrated.

Lights. The first analysis in this group was made in terms of the

transfer effects in going from a low to a high signal rate. The mean percentage detections for the two groups were 86.9% for the control group and 78% for the transfer group.

A Kruskal-Wallis one-way analysis of variance yielded an $\underline{H}$ of 0.63 with a $\underline{p}$ greater than .05. There was no significant transfer in going from the low to the high signal rate.

A second analysis was made in terms of the transfer effects in going from a high to a low signal rate. The mean percentage correct detections for the two groups were 77% for the control group and 84% for the transfer group. A Kruskal-Wallis one-way analysis of variance yielded an $\underline{H}$ of 1.32 with a $\underline{p}$ greater than .05. There was no significant transfer in going from high to low signal rates.

A final analysis compared performance at the high signal rate with performance at the low signal rate regardless of which order the individual participated in these conditions. As with the meter analyses, this analysis was possible because of the failure to find significant transfer effects between signal rates.

The mean percentage correct detections for the high signal rate was 83%; the mean for the low signal rate was 80%. A Wilcoxon matched-pairs signed-ranks test on these data yielded a $\underline{Z}$ of 1.68 with an associated $\underline{p}$ of less than .05. In this case, the high signal rate resulted in significantly superior detection performance.

Latencies. Three analyses were made of the latency data for this study. Differences between the N's shown in the tables and the total N's for the groups are the result of eliminating individuals for whom insufficient latencies were available for analysis.

The first analysis consisted of a comparison of the light and null-meter displays over three equal time periods. These results are given in Table 12. An analysis of variance for these data is presented in Table 13. The only significant F for this analysis (10.29 $p < .01$, 2 and 256 df) was that for time periods. Examination of Table 12 indicates that this effect resulted entirely from a systematic increase in latencies with time for the light display. The null-meter data showed practically no variation at all. These are the first latency data in this entire series of studies demonstrating a significant relationship between latencies and time.

The second analysis was on the low signal rate data. These latencies were again analyzed in terms of the two displays and three time periods. The results are given in Table 14. An analysis of variance for these data is presented in Table 15. The only significant F (4.52 $p < .05$, 2 and 112 df) was for the interaction between time periods and displays. As in the preceding analysis this F was the result of the increase in latencies for the light display after the first time period.

The final analysis was on the high signal rate data. Again, the latencies were analyzed in terms of the two displays and three time periods. These data are presented in Table 16. The light display data tend to show a systematic increase in latencies over time periods, but the effect is not reflected in the accompanying analysis of variance.

TABLE 12

Response Latencies* for Lights and Meters

	TIME PERIOD			
CONDITION	1	2	3	AVERAGE
Lights	1.23	1.46	1.58	1.43
Null-Meters	1.47	1.48	1.46	1.47
AVERAGE	1.35	1.47	1.52	

*Arbitrary units: one unit equals 1.25 sec. approximately.

TABLE 13

Analysis of Variance for Light and Meter Latencies

SOURCE	SS	df	MS	F
Lights Vs. Meters	.31	1	.31	--
S's in Same Grp.	98.30	128	.77	
TOTAL	98.61	129		
Between Periods	4.23	2	2.12	10.29*
Periods x Cond.	.89	2	0.45	2.16
Pooled Ss x Periods	52.95	256	0.21	
TOTAL	58.07	260		
TOTAL	156.68	389		

* $p < .01$

TABLE 14

Response Latencies* for Lights and Meters
at Low Signal Rate

TIME PERIOD

CONDITION	1	2	3	AVERAGE
Lights	1.19	1.57	1.63	1.46
Null-Meters	1.50	1.45	1.41	1.45
AVERAGE	1.35	1.51	1.52	

*Arbitrary units: one unit equals 1.25 sec. approximately.

TABLE 15

Analysis of Variance for Low Signal Rate

SOURCE	SS	df	MS	F
Lights VS. Meters	.00	1	.00	--
S's in Same Grp.	49.91	56	.89	
TOTAL	49.91	57		
Between Periods	1.09	2	.55	2.12
Periods x Cond.	2.33	2	1.16	4.52*
Pooled Ss x Periods	28.85	112	.26	
TOTAL	32.27	116		
TOTAL	82.18	173		

* $p < .05$

TABLE 16

Response Latencies* for Lights and Meters
at High Signal Rate

TIME PERIOD

CONDITION	1	2	3	AVERAGE
Lights	1.27	1.36	1.53	1.39
Null-Meters	1.47	1.50	1.52	1.50
AVERAGE	1.37	1.43	1.53	

*Arbitrary units: one unit equals 1.25 sec. approximately.

Discussion.

None of the analyses relating to transfer effects in this study yielded significant differences between treatments. The failure to find differences under the specific conditions of this experiment, of course, does not prove that some transfer effect does not exist. However, the data suggest strongly that such effects must be rather short-lived and relatively weak and of small practical significance.

The finding that detection performance is superior with a high signal rate to that found with a low signal rate with the light display is in line with the evidence from other studies in the literature and adds further confirming evidence for the validity of the light task as a vehicle for vigilance research.

The finding of greatest interest in this study was the highly significant difference between displays. Whereas the data for the light display showed the characteristic failures to detect, the null-meters did not. The evidence is quite clear that the null-meter task _as it is presently constituted_ is not a suitable vehicle for vigilance research. This conclusion is further supported by the latency data. The meter display yielded a constant level of latencies throughout all periods of all conditions in contrast to the light data which showed a systematic increase in response latencies over time periods.

The statement that the null-meter task is not a suitable vehicle for vigilance research requires some further explanation. A defining characteristic of "vigilance" is a demonstrated performance decrement over time. When a given task fails to demonstrate such a systematic reduction in performance level then no vigilance problem exists in terms of this situation and it is not possible to usefully employ such a task for vigilance research. Clearly, it is necessary to employ a task in which it can be demonstrated that, before the administration of experimental variables, a vigilance decrement will occur.

It is well established that displays can be designed which will largely eliminate the vigilance affect by presenting intense signals over relatively long periods of time. In the present study the nature of the meter display was such that the signals were easily discriminable over a relatively long period of time (on the order of six times as long as the light signal). False, or distracting, movements of the pointer were not employed so that any movement of the pointer was always correlated with a signal. Thus, in hindsight, it is not at all surprising that this display yielded no decrement over the time period sampled in this study. It is clear that the characteristics of the meter display employed in this study are not those found in operational meter displays, and for this reason, the present results are probably not applicable to such situations.

An obvious implication of the present results is that the use of null-meters with the characteristics of the meters employed in this would provide a simple solution to the vigilance problem. However, it should be noted that the current program of research is predicated on

the assumption that tasks do, and will exist in which vigilance decrements are a significant characteristic, and for which apparatus modifications (i.e., human engineering solutions) are not feasible. For such situations, a reasonable alternative solution is the manipulation of job and environmental factors to optimize operator performance, and it is the determination of such optimal conditions that is the objective of the present research.

The failure to demonstrate a vigilance effect with the null-meter display and the tendency for some of the conditions in the earlier experiments in this series to yield large numbers of perfect detection performances suggests that more careful consideration be given to the nature of the displays employed in future studies. It seems highly probable that an increase in task difficulty would have a salutary effect on the research. It would tend to increase the sensitivity of the task to the effects of the experimental variables at higher levels of performance, permitting finer discriminations between variables, and would at the same time yield less truncated distributions of scores, allowing for more sophisticated statistical analyses.

In addition, a change in the experimental procedures to employ a brief pre-testing session would permit better control of the individual differences variables and an extension of the test length to a length of approximately two and one half hours would tend also to increase test sensitivity.

All of these possibilities will be given consideration in future studies.

SUMMARY AND CONCLUSIONS

Seven experiments were conducted, ~~in this series~~. These included comparisons between multiple and single monitored systems; paired and isolated monitors at high and at low signal rates; spaced and massed monitoring at high and at low signal rates; a comparison between spaced, paired, and a combination of spaced and paired monitoring; and a comparison of transfer effects in going from high to low and from low to high signal rates in terms of two different displays. The results of these studies and the conclusions growing out of these results are summarized under four headings: ~~These are~~ multiple monitoring, spaced monitoring, spaced-paired monitoring, and transfer.

Multiple Monitoring

Three studies were conducted on the effects of multiple monitoring. The first study compared the detection output of multiple-monitored with individually monitored systems and demonstrated significantly superior detection levels for conditions in which two men monitored the same system. When individually monitored systems were randomly paired, however, and compared with cooperatively and competitively multiple-monitored systems the differences in detection levels were not significant, although competitive multiple-monitoring resulted in 6% more detections over all.

The second study examined the effects of pairing on individual performance when a high signal rate was employed. The results indicated

that individual detection performances tended to improve when the individual monitored in the presence of a second monitor but that the effect was specific to the pairs involved.

A third study examined the effects of pairing on individual performance when a low signal rate was employed. In contrast to the results of the second study, the results of the third study indicated no over-all facilitation of individual performances when individuals were paired. However, as in the second study, a significant relationship was demonstrated between the performances of paired individuals.

In general, it can be concluded that multiple-monitoring results in significantly improved detection performance for a system and that under some circumstances will yield improved individual performance as well. When individual performance is not improved it does not appear to be reduced as a result of pairing.

Spaced Monitoring

Two studies on the effects of spacing were conducted. The first study examined the effects of brief rest pauses on detection performance when a high signal rate was employed. The results indicated significantly superior detection performance over the entire time period sampled when rest pauses were employed.

The second study examined the effects of brief rest pauses on detection performance when a low signal rate was employed. As in the

first study, the results indicated significantly superior detection performance over the entire time period sampled when rest pauses were employed.

The results of these studies in combination lead to the conclusion that the effects of rest pauses are both powerful and general in their effects and suggest that pauses of even briefer duration may be equally effective in maintaining a high level of performance.

Spaced-Paired Monitoring

A single experiment was performed to determine the comparative effectiveness of pairing, rest pauses, and a combination of pairing and rest pauses. The results of this study, while statistically non-significant, were in the predicted direction. The combination of spacing and pairing produced the highest over-all detection level (96%) of any of the conditions employed in this series and this level was maintained throughout the entire time period sampled. The spaced condition produced the next highest detection level (93%), and the pairing condition yielded the lowest level (86%), although it should be noted that in the first study the treatment of competitive pairs as a single system output yielded 95% detections.

In general, it can be concluded from the results of this series of studies that, when pairing and spacing are feasible in the operational situation and a relatively high signal rate can be anticipated, some combination of these factors will lead to near-optimum detection levels over fairly extended periods of time.

Figure 10 summarizes the major comparisons of interest in this group of studies. In these analyses the term following the magnitude symbol in the first column of the table served as the standard against which the term preceding the magnitude symbol was compared. The standard error of the difference between means for the two terms was computed and the upper and lower 95% confidence limits of the mean difference were determined. These limits and the mean difference were then converted to percentages and are presented in this form in the Table. Those cases in which the confidence limits do not overlap with the 0% line indicates the degree to which the mean differences fall below this level.

Transfer

A single study was performed to determine the effects of transferring from one signal rate to another. No transfer was demonstrated either in going from a low to a high, or from a high to a low signal rate and it was concluded that if transfer effects are present they are of such small magnitude as to be of little practical concern.

This study found confirming evidence for superior performance with a higher signal rate.

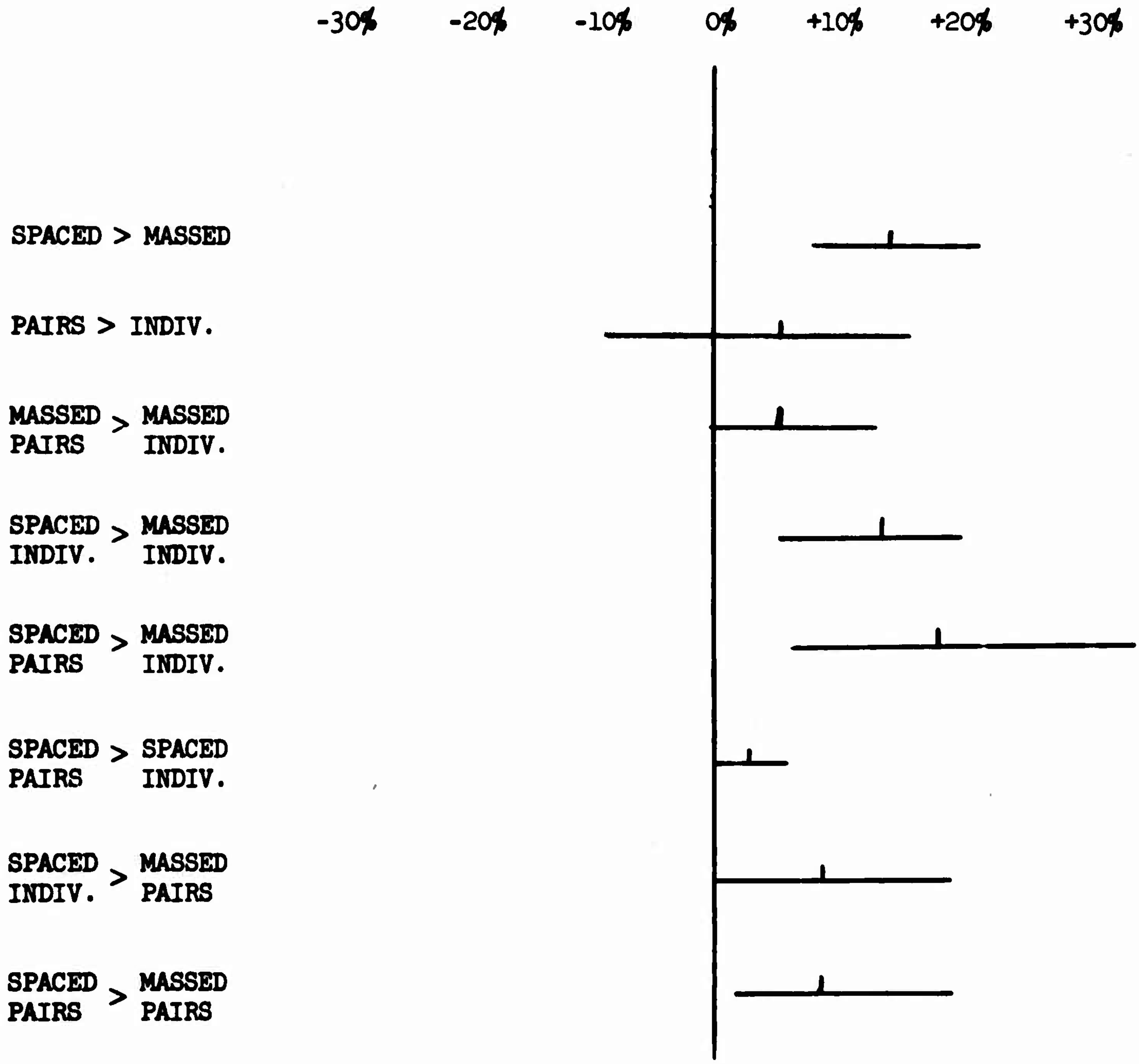

FIG. 10. MAJOR GROUP COMPARISONS IN TERMS OF MEAN PERCENT DIFFERENCES.

The finding of greatest interest was the failure to demonstrate any vigilance effect employing a null-meter display. As a result of this study consideration is being given to modification of the displays employed in the later phases of this program, as well as to changes in procedures for testing.